

## **CHAPTER 2.—SELECTION OF GAGING-STATION SITES**

### **INTRODUCTION**

The general location of a gaging station is dependent on the specific purpose of the streamflow record. If the streamflow record is needed for the design or operation of a water project, such as a dam and reservoir, the general location of the gaging station obviously will be in the vicinity of the water project. The selection of a gaging-station site becomes complicated, however, when the station is to be one of a network of stations whose records are required for study of the general hydrology of a region. Such studies are used to inventory the regional water resource and formulate long-range water-development plans. In that situation, attention to hydrologic principles is required in selecting the general locations of the individual stations in the network to ensure that optimum information is obtained for the money spent in data collection.

A discussion of the design of gaging-station networks is beyond the scope of this manual and for the purpose of this chapter we will assume that the general location of a proposed gaging station has been determined. The discussion that follows will be concerned with the hydraulic considerations that enter into the selection of the precise location of the gage to obtain the best locally available conditions for the measurement of stage and discharge and for the development of a stable discharge rating.

### **CONSIDERATIONS IN SPECIFIC SITE SELECTION**

After the general location of a gaging station has been determined, a specific site for its installation must be selected. For example, if the outflow from a reservoir is to be gaged to provide the streamflow data needed for managing reservoir releases, the general location of the gaging station will be along the stretch of stream channel between the dam and the first stream confluence of significant size

downstream from the dam. From the standpoint of convenience alone, the station should be established close to the dam, but it should be far enough downstream from the outlet gates and spillway outlet to allow the flow to become uniformly established across the entire width of the stream. On the other hand the gage should not be located so far downstream that the stage of the gaged stream may be affected by the stage of the confluent stream. Between those upstream and downstream limits for locating the gage, the hydraulic features should be investigated to obtain a site that presents the best possible conditions for stage and discharge measurement and for developing a stable stage-discharge relation. If the proposed gaging station is to be established for purely hydrologic purposes, unconnected with the design or operation of a project, the general location for the gage will be the stretch of channel between two large tributary or confluent streams. The same consideration will apply in the sense that the gage should be far enough downstream from the upper tributary so that flow is fairly uniformly established across the entire width of stream, and far enough upstream from the lower stream confluence to avoid variable backwater effect. Those limits often provide a reach of channel of several miles whose hydraulic features must be considered in selecting a specific site for the gage installation.

The ideal gage site satisfies the following criteria:

1. The general course of the stream is straight for about 300 ft (approx. 100 m) upstream and downstream from the gage site.
2. The total flow is confined to one channel at all stages, and no flow bypasses the site as subsurface flow.
3. The streambed is not subject to scour and fill and is free of aquatic growth.
4. Banks are permanent, high enough to contain floods, and are free of brush.
5. Unchanging natural controls are present in the form of a bedrock outcrop or other stable riffle for low flow and a channel constriction for high flow—or a falls or cascade that is unsubmerged at all stages (chap. 3).
6. A pool is present upstream from the control at extremely low stages to ensure a recording of stage at extremely low flow, and to avoid high velocities at the streamward end of gaging-station intakes during periods of high flow.
7. The gage site is far enough upstream from the confluence with another stream or from tidal effect to avoid any variable influence the other stream or the tide may have on the stage at the gage site.
8. A satisfactory reach for measuring discharge at all stages is available within reasonable proximity of the gage site. (It is not nec-

essary that low and high flows be measured at the same stream cross section.)

9. The site is readily accessible for ease in installation and operation of the gaging station.

Rarely will an ideal site be found for a gaging station and judgment must be exercised in choosing between adequate sites, each of which has some shortcomings. Often, too, adverse conditions exist at all possible sites for installing a needed gaging station, and a poor site must be accepted. For example, all streams in a given region may have unstable beds and banks, which result in continually changing stage-discharge relations.

The reconnaissance for a gaging site properly starts in the office where the general area for the gage site is examined on topographic, geologic, and other maps. Reaches having the following pertinent characteristics should be noted: straight alinement, exposed consolidated rock as opposed to alluvium, banks subject to overflow, steep banks for confined flow, divided channels, possible variable backwater effect from a tributary or confluent stream or from a reservoir, and potential sites for discharge measurement by current meter. The more favorable sites will be given critical field examination; they should be marked on the map, access roads should be noted, and an overall route for field reconnaissance should be selected.

In the field reconnaissance the features discussed earlier are investigated. With regard to low flow, a stable well-defined low-water control section is sought. In the absence of such a control, the feasibility of building an artificial low-water control is investigated. If a site on a stream with a movable bed must be accepted—for example, a sand-channel stream—it is best to locate the gage in as uniform a reach as possible, away from obstructions in the channel, such as bridges, which tend to intensify scour and fill. (See page 377.) Possible backwater resulting from aquatic growth in the channel should also be investigated. If the gage is to be located at a canyon mouth where the stream leaves the mountains or foothills to flow onto an alluvial plain or fan, reconnaissance current-meter measurements of discharge should be made during a low-flow period to determine where the seepage of water into the alluvium becomes significant. The station should be located upstream from the area of water seepage in order to gage as much of the surface flow as possible; the subsurface flow or underflow that results from channel seepage is not “lost” water, but is part of the total water resource.

With regard to high stages, high-water marks from major floods of the past are sought and local residents are questioned concerning historic flood heights. Such information is used by the engineer in making a judgment decision on the elevation at which the stage-

recorder must be placed to be above any floods that are likely to occur in the future. The recorder shelter should be so located as to be sheltered from waterborne debris during major floods. Evidence is also sought concerning major channel changes, including scour and deposition at streambanks, that occurred during notable floods of the past. That evidence, if found, gives some indication of changes that might be expected from major floods of the future.

The availability of adequate cross sections for current-meter measurement of discharge should also be investigated. Ideally, the measurement cross section should be of fairly uniform depth, and flow lines should be parallel and fairly uniform in velocity throughout the cross section. The measurement section should be in reasonable proximity to the gage to avoid the need for adjusting measured discharge for change in storage, if the stage should change rapidly during a discharge measurement. However a distance of as much as 0.5 mi (approx. 1 km) between gage and measuring section is acceptable if such a distance is necessary to provide both a good stage-measurement site and a good discharge-measurement site. Low-flow discharge measurements of all but the very large streams are made by wading. For flows that cannot be safely waded, the current meter is operated from a bridge, cableway, or boat. It is most economical to use an existing bridge for that purpose, but in the absence of a bridge, or if the measuring section at a bridge site is poor, a suitable site should be selected for constructing a cableway. If construction of a cableway is not feasible because of excessive width of the river, high-water measurements will be made by boat when safe to do so. The cross section used for measuring high flows is rarely suitable for measuring low flows, and wading measurements are therefore made wherever measuring conditions are most favorable.

Consideration should be given to the possibility of variable backwater effect from a stream confluence or reservoir downstream from the general location of the required gaging station. Without knowledge of stage and discharge at a potential gage site and of concurrent stage at the stream confluence or reservoir, the engineer can only conjecture concerning the location on the stream where backwater effect disappears for various combinations of discharge and stage. A safe rule is the following: Given a choice of several acceptable gaging sites on a stream, the gaging site selected should be the one farthest upstream from the possible source of variable backwater. If it is necessary to accept a site where variable backwater occurs, a uniform reach for measurement of slope should be sought, along with a site for the installation of an auxiliary gage. If a gaging station must be placed in a tide-affected reach, the unsteady flow that must be gaged will also require an auxiliary gage, but in addition line

power must be available to insure the synchronized recording of stage at the two gages. The availability of line power or telephone lines is also a consideration, where needed for special instrumentation or for the telemetering units that are often used in flood-forecasting and flood-warning systems.

In cold regions the formation of ice always presents a problem in obtaining reliable winter records of streamflow. However in regions that are only moderately cold, and therefore subject to only moderate ice buildup, forethought in the selection of gage sites may result in streamflow records that are free of ice effect. Gage sites that are desirable from that standpoint are as follows:

1. Below an industrial plant, such as a paper mill, steel mill, thermal powerplant, or coal mine. "Waste" heat may warm the water sufficiently or impurities in the water may lower the freezing point to the extent that open-water conditions always prevail.
2. Immediately downstream from a dam with outlet gages. Because the density of water is maximum at a temperature of  $4^{\circ}\text{C}$ , the water at the bottom of a reservoir is commonly at or near that temperature in winter. Most outlet gates are placed near the bottom of the dam, and the water released is therefore approximately  $4^{\circ}\text{C}$  above freezing. It would take some time for that water to lose enough heat to freeze.
3. On a long fairly deep pool just upstream from a riffle. A deep pool will be a tranquil one. Sheet ice will form readily over a still pool, but the weather must be extremely cold to give complete cover on the riffle. At the first cold snap, ice will form over the pool and act as an insulating blanket between water and air. Under ice cover the temperature of the streambed is generally slightly above the freezing point and may, by conduction and convection, raise the water temperature slightly above freezing, even though water enters the pool at  $0^{\circ}\text{C}$ . That rise in temperature will often be sufficient to prevent ice formation on the riffle.

After the many considerations discussed on the preceding pages have been weighed, the precise sites for the recording stage gage and for the cableway for discharge measurements (if needed) are selected. Their locations in the field are clearly marked and referenced. The maximum stage at which the low-water control will be effective should be estimated; the intakes to the stage recorder should be located upstream from the low-water control, a distance equal to at least three times the depth of water on the control at that estimated maximum stage. If the intakes are located any closer than that to the control, they may lie in a region where the streamlines have vertical curvature; intake location in that region is hydraulically undesirable.

The gaging station on the Kaskaskia River at Bondville, Ill., shown

in figure 1, satisfies most of the requirements discussed in this chapter. Low-flow measurements are made by wading upstream from the control. The bridge site provides accessibility, convenience to power lines, and a good location for an outside reference gage, which is shown on the downstream parapet wall of the bridge.

Up to this point there has been no discussion of specific site location for crest-stage gages. Those gages provide peak-discharge data only. Where possible they should be installed upstream from road culverts, which act as high-water controls. The specific site for a gage is at a distance of one culvert width upstream from the culvert inlet. In the absence of such control structures, the crest-stage gage should be installed in a straight reach of channel that can be utilized in computing peak discharge by the slope-area method (chap. 9).

### SELECTED REFERENCES

- Carter, R. W., and Davidian, Jacob, 1968, General procedure for gaging streams: U.S. Geol. Survey Techniques Water-Resources Inv., book 3, chap. A6, p. 2-3.  
World Meteorological Organization, 1974, Guide to hydrometeorological practices [3d ed.]: WMO-no. 168, p. 3.1-3.4, 3.13-3.16.

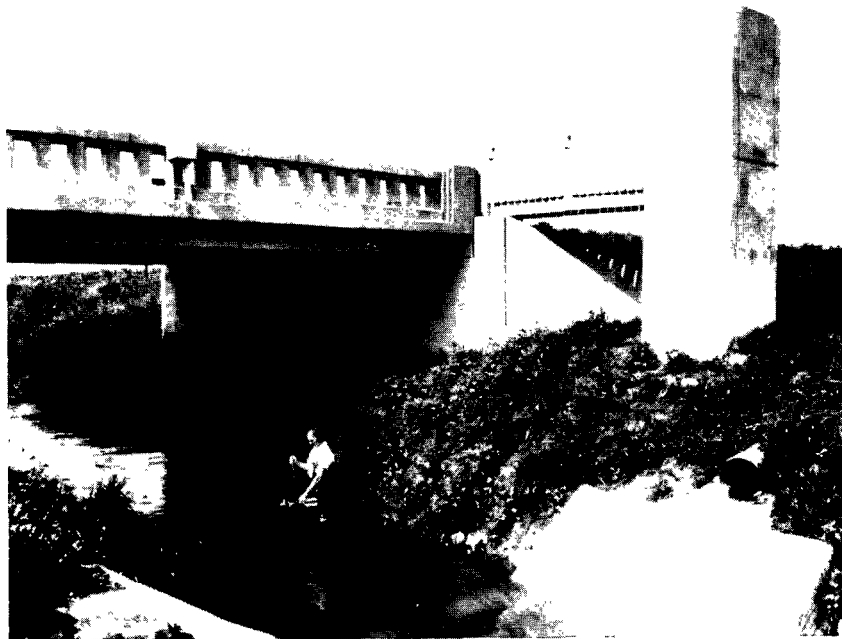


FIGURE 1.—Gage, concrete control, outside gage on bridge, and an engineer making a wading measurement, Kaskaskia River at Bondville, Ill.